

APPENDIX D

CALTRANS FISH PASSAGE DESIGN FORMS

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- Form 6E - Hydraulic Rock Weir Design Option

APPENDIX D

FORM 1 - EXISTING DATA AND INFORMATION SUMMARY

EXISTING DATA AND INFORMATION SUMMARY

FORM 1

Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:
Proposed Project Type	<input type="checkbox"/> New Culvert	<input type="checkbox"/> New Bridge	
	<input type="checkbox"/> Replacement Culvert	<input type="checkbox"/> Replacement Bridge	
	<input type="checkbox"/> Retrofit Culvert	<input type="checkbox"/> Retrofit Bridge	
	<input type="checkbox"/> Proposed Culvert Length= ft	<input type="checkbox"/> Proposed Bridge Length= ft	
	<input type="checkbox"/> Other	<input type="checkbox"/> Other	
Design Species/Life Stage	<input type="checkbox"/> All Species	Source: Contact: Date:	
	<input type="checkbox"/> Adult Anadromous Salmonids		
	<input type="checkbox"/> Adult Non-Anadromous Salmonids		
	<input type="checkbox"/> Juvenile Salmonids		
	<input type="checkbox"/> Native Non-Salmonids		
	<input type="checkbox"/> Non-Native Species		
Collect Existing Data			
Included in Caltrans Culvert Inventory		<input type="checkbox"/> Yes	<input type="checkbox"/> No
As-Built Drawings		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Assessor's Parcel Map		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Previous Studies Performed: (i.e. FEMA Flood Insurance Studies, Army Corps of Engineering Studies, Other)			
Hydrology Analysis		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Hydraulics Analysis		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Floodplain Mapping		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Other Studies Types Available: (i.e. Watershed Management Plans, Stream Restoration Plans, Other)		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Existing Land Use Map		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Proposed Land Use Map		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Precipitation Gage Data		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Stream Flow Gage Data		<input type="checkbox"/> Yes	<input type="checkbox"/> No

EXISTING DATA AND INFORMATION SUMMARY**FORM 1**

Topographic Mapping:
(i.e. USGS Topographic Quadrangle, DEM Data, LIDAR Data, Other)

☐ Yes ☐ No

District Hydraulics Library

☐ Yes ☐ No

Obtain Access Permission

Will Project study limits extend beyond Caltrans R/W? ☐ Yes ☐ No

If yes, obtain right-of-entry.

Contact Report Index Attached

☐ Yes ☐ No

Existing Information Index Attached

☐ Yes ☐ No

CONTACT REPORT INDEX

[illegible]

EXISTING INFORMATION INDEX	
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Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:

[illegible]

APPENDIX D
FORM 2 - SITE VISIT SUMMARY

SITE VISIT SUMMARY

FORM 2

Project Information

Computed:

Date:

Checked:

Date:

Stream Name:

County:

Route:

Postmile:

Obtain Physical Characteristics of Existing Culvert

Confined Spaces

Is the culvert height 5 ft or greater?

☐ Yes ☐ No

Can you stand up in the culvert?

☐ Yes ☐ No

Can you see all the way through the culvert?

☐ Yes ☐ No

Can you feel a breeze through the culvert?

☐ Yes ☐ No

If answer is "No" to any of the above questions, do not enter the culvert without confined spaces equipment for surveying.

Inlet Characteristics

Inlet Type

☐ Projecting

☐ Headwall

☐ Wingwall

☐ Flared end section

☐ Segment connection

Inlet Condition

☐ Channel scour

☐ Excessive deposition

☐ Debris accumulation

☐ None applicable

Inlet Apron

☐ Channel scour

☐ Excessive deposition

☐ Debris accumulation

☐ None applicable

Skew Angle:

°

Upstream Invert Elevation:

ft (NGVD 29 or NAVD 88)

Barrel Characteristics

Diameter:

in

Fill height above culvert:

ft

Height/Rise:

ft

Length:

ft

Width/Span:

ft

Number of barrels:

Culvert Type

☐ Arch

☐ Box

☐ Circular

☐ Pipe-Arch

☐ Elliptical

Culvert Material

☐ HDPE

☐ Steel Plate Pipe

☐ Concrete Pipe

☐ Spiral Rib / Corrugated Metal Pipe

Barrel Condition

☐ Corrosion

☐ Debris accumulation

☐ Structural damage

☐ Abrasion

☐ Bedload accumulation

☐ None applicable

SITE VISIT SUMMARY

FORM 2

Horizontal alignment breaks:		ft	Vertical alignment breaks:		ft
Outlet Characteristics					
Outlet Type	<input type="checkbox"/> Projecting		<input type="checkbox"/> Headwall		<input type="checkbox"/> Wingwall
	<input type="checkbox"/> Flared end section		<input type="checkbox"/> Segment connection		
Outlet Condition	<input type="checkbox"/> Scour hole		<input type="checkbox"/> Backwatered		<input type="checkbox"/> Debris accumulation
	<input type="checkbox"/> Perched		Outlet elevation drop: ft		
				Outlet drop condition:	
				Scour hole depth: ft	
Outlet Apron	<input type="checkbox"/> Channel scour		<input type="checkbox"/> Excessive deposition		<input type="checkbox"/> Debris Accumulation
Skew Angle:		°	Downstream Invert Elevation: ft (NGVD 29 or NAVD 88)		
Obtain Physical Characteristics of Existing Bridge					
Elevation of high chord (top of road):		ft	Elevation of low chord: ft		
Channel Lining	<input type="checkbox"/> No lining		<input type="checkbox"/> Concrete		<input type="checkbox"/> Rock
		<input type="checkbox"/> Other			
Skew Angle:		°	Bridge width (length): ft		
Pier Characteristics (if applicable) <input type="checkbox"/>					
Number of Piers:			Upstream cross-section starting station: ft		
Pier Width:		ft	Downstream cross-section starting station: ft		
Pier Centerline Spacing:		ft			
Pier Shape	<input type="checkbox"/> Square nose and tail		<input type="checkbox"/> Semi-circular nose and tail		<input type="checkbox"/> 90° triangular nose and tail
	<input type="checkbox"/> Twin-cylinder piers with connecting diaphragm		<input type="checkbox"/> Twin-cylinder piers without connecting diaphragm		<input type="checkbox"/> Ten pile trestle bent
Pier Condition	<input type="checkbox"/> Scour		<input type="checkbox"/> Corrosion		<input type="checkbox"/> Debris accumulation
Skew angle		°			
Channel Characteristics					
Hydraulic Structure Roughness Coefficients					
(Source: Caltrans Highway Design Manual Table 864.3A)			(Source: HEC-RAS User's Manual)		
Type of Structure	n- value		Type of Structure	n- value (normal)	

SITE VISIT SUMMARY

FORM 2

Lined Channels:		Corrugated Metal:	
Portland Cement Concrete	0.014	Subdrain	0.019
Air Blown Mortar (troweled)	0.012	Storm drain	0.024
Air Blown Mortar (untroweled)	0.016	Wood:	
Air Blown Mortar (roughened)	0.025	Stave	0.012
Asphalt Concrete	0.018	Laminated, treated	0.017
Sacked Concrete	0.025	Brickwork:	
Pavement and Gutters:		Glazed	0.013
Portland Cement Concrete	0.015	Lined with cement mortar	0.015
Asphalt Concrete	0.016		
Depressed Medians:			
Earth (without growth)	0.040		
Earth (with growth)	0.050		
Gravel	0.055		
Recommended Permissible Velocities for Unlined Channels (Source: Caltrans Highway Design Manual, Table 862.2)			
Type of Material in Excavation Section	Intermittent Flow (f/s)	Sustained Flow (f/s)	
Fine Sand (Noncolloidal)	2.6	2.6	
Sandy Loam (Noncolloidal)	2.6	2.6	
Silt Loam (Noncolloidal)	3.0	3.0	
Fine Loam	3.6	3.6	
Volcanic Ash	3.9	3.6	
Fine Gravel	3.9	3.6	
Stiff Clay (Colloidal)	4.9	3.9	
Graded Material (Noncolloidal)			
Loam to Gravel	6.6	4.9	
Silt to Gravel	6.9	5.6	
Gravel	7.5	5.9	

SITE VISIT SUMMARY

FORM 2

Coarse Gravel	7.9	6.6
Gravel to Cobbles (Under 150mm)	8.8	6.9
Gravel and Cobbles Over 200mm)	9.8	7.9
Flow Estimation cfs	<input type="checkbox"/> Supercritical flow	<input type="checkbox"/> Subcritical flow
Channel Cross-Section Schematic		Channel depth = ft
Average Active Channel Width Take at least five channel width measurments to determine the active channel width. The active channel stage or ordinary high water level is the elevation delineating the highest water level that has been maintained for a sufficient period of time to leave evidence on the landscape.		Average Active Channel Width = ft
1) ft	2) ft	3) ft
Boundary Conditions The normal depth option (slope area method) can only be used as a downstream boundary condition for an open-ended reach. Is normal depth appropriate? If no, what is the known starting water surface elevation?		4) ft
Upstream		slope ft/ft
Downstream		slope ft/ft
Known starting water surface elevation Source:		ft
General Considerations		
Identify Physical Restrictions	<input type="checkbox"/> Right-of-way	<input type="checkbox"/> Utility conflict
	<input type="checkbox"/> Man-made features	<input type="checkbox"/> Natural features
	<input type="checkbox"/> Vegetation	<input type="checkbox"/> Other
Cross-Section Sketches Attached <input type="checkbox"/> Yes <input type="checkbox"/> No		
Site Photograph Documentation Attached <input type="checkbox"/> Yes <input type="checkbox"/> No		
Channel / Overbank Manning's n-value Calculation Attached <input type="checkbox"/> Yes <input type="checkbox"/> No		
Field Notes Attached <input type="checkbox"/> Yes <input type="checkbox"/> No		

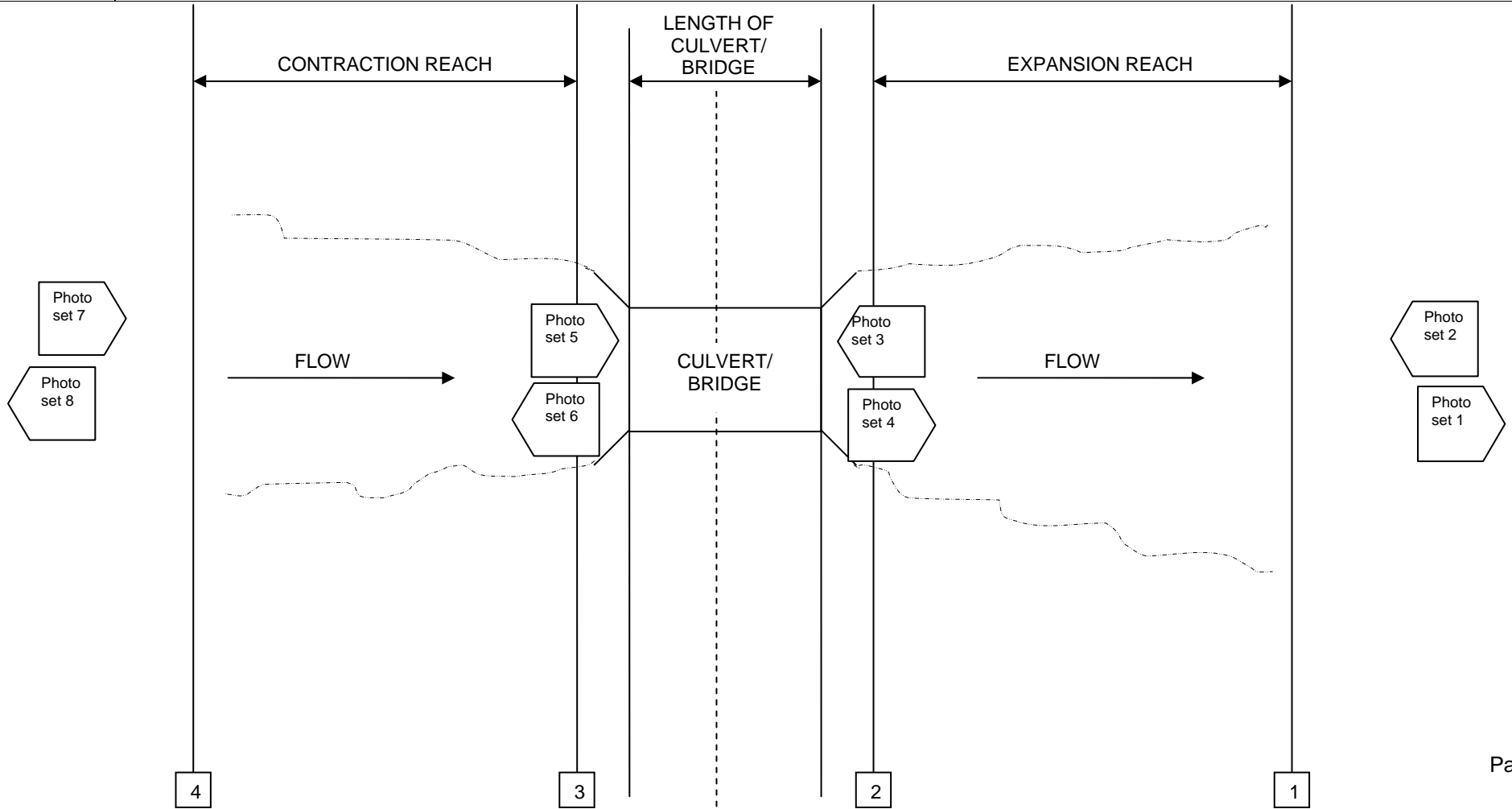
CROSS-SECTION SKETCH

Upstream face of structure:

Downstream face of structure:

SITE PHOTOGRAPH DOCUMENTATION

Project Information				Computed:		Date:		
				Checked:		Date:		
Stream Name:			County:		Route:		Postmile:	
Crossing Type	<input type="checkbox"/> Culvert			<input type="checkbox"/> Bridge			<input type="checkbox"/> Other Type/Comments	
Distance From:	X-sec. 1 to X-sec. 2: ft		X-sec. 2 to DS face of structure ft		US face of structure to X-Sec. 3 ft		X-sec. 3 to X-sec. 4 ft	
Distance From:	Photo Sets 1 & 2 to DS face of structure ft		Photo Sets 3 & 4 to DS face of structure ft		Photo Sets 5 & 6 to US face of structure ft		Photo Sets 7 & 8 to US face of structure ft	
Length of Culvert/Bridge:	ft							



SITE PHOTOGRAPH DOCUMENTATION

Photo Descriptions:

Photo Set 1	
Photo Set 2	
Photo Set 3	
Photo Set 4	
Photo Set 5	
Photo Set 6	
Photo Set 7	
Photo Set 8	

Manning's n Computation - Overbank

Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:
Aerial Picture Attached:			
Photographs (#'s and locations)			

Is roughness uniform throughout the reach? _____

Note: If not, n-value should be assigned for the AVERAGE condition of the reach

Is roughness uniformly distributed along the cross section? _____

Is a division between the channel and floodplain necessary? _____

Calculation of n-value:

$$n = (nb + n1 + n2 + n3 + n4)m$$

where:

nb = base n value for surface

n1 = surface irregularity factor

n2 = cross section variation factor

n3 = obstructions factor

n4 = vegetation factor

m = sinuosity/meandering factor

Description of Range

median size between 1" and 2.5" = 0.028 to 0.035, between 2.5" and 10" = 0.030 to 0.050

smooth = 0 up to severe at 0.020

gradual = 0 up to alternating frequently at 0.015

assumed to equal 0

small = 0.002 to very large (average depth of flow is less than 1/2 height of vegetation) at 0.100

equals 0 for floodplains

Base n value for surface

nb:	Sand channel?	_____ if yes, median size of bed material? _____	median size (in)	nb
			0.008	0.012
			0.012	0.017
			0.016	0.020
			0.020	0.022
			0.024	0.023
			0.031	0.025
			0.039	0.026
	All other channels:		median size (in)	nb
			.04 to .08	0.026 to 0.035
			1 to 2.5	0.028 to 0.035
			2.5 to 10	0.030 to 0.050
			>10	0.040 to 0.070

Notes:

nb = _____

Surface Irregularity

n1:	Smooth	Compares to the smoothest, flattest floodplain in a given bed material.	if yes, n1 = 0
	Minor	Is the floodplain slightly irregular in shape. A few rises and dips or sloughs may be more visible on the floodplain.	if yes, n1 = 0.001 - 0.005
	Moderate	Has more rises and dips. Sloughs and hummocks may occur.	if yes, n1 = 0.006 - 0.010
	Severe	Floodplain very irregular in shape. Many rises and dips or sloughs are visible.	if yes, n1 = 0.011 - 0.020

n1 = _____

Notes:

Cross Section Variation Factor

Manning's n Computation - Overbank

$$n_2 = \underline{0.000}$$

Notes: Not applicable to floodplains.

Obstructions factor

n3:	Negligible	Does the stream have a few scattered obstructions that occupy < 5% of the cross-sectional area?	if yes, $n_3 = 0.000 - 0.004$
	Minor	Obstructions occupy < 15% of the cross-sectional area and the spacing between obstructions is such that the sphere of influence doesn't extend to other obstructions?	if yes, $n_3 = 0.005 - 0.015$
	Appreciable	Obstructions occupy 15% - 50% of the cross-sectional area and the spacing between obstructions is small enough to be additive?	if yes, $n_3 = 0.020 - 0.030$

$$n_3 = \underline{\hspace{2cm}}$$

Notes:

Vegetation factor

n4:	Small	Does the channel have dense growth of flexible turf grass or weed growth where the flow is at least 2 times the height of the vegetation; tree seedlings of willows, cottonwoods, etc where the average depth of flow is at least three times the height of the vegetation?	if yes, $n_4 = 0.002 - 0.010$
	Medium	Does the channel have turf grass where the average depth of flow is 1-2 times the height of the vegetation; moderately stemmy grass, weeds or tree seedlings growing where the flow is 2-3 times the height of vegetation? Brushy, moderately dense vegetation, similar to 1-2 year old willow trees in dormant season.	if yes, $n_4 = 0.010 - 0.025$
	Large	Does the channel where the average. depth of flow is equal to the height of the vegetation; 8 to 10 year old. willows, cottonwoods intergrown with weeds and brush; where the R = 1.97 ft or bushy willows of 1 year old are in the channel bottom, where R = 2.00 ft?	if yes, $n_4 = 0.025 - 0.050$
	Very large	Does the channel have turf grass growing where the average depth of flow < 1/2 the height of the vegetation; bushy willows about 1 year old. with weeds intergrown on side slopes; dense cattails in channel bottom; trees intergrown with weeds and brush?	if yes, $n_4 = 0.050 - 0.100$
	Extreme	Does the channel have dense bushy willow, mesquite, and salt cedar (full foliage), or heavy stand of timber, few down trees, depth of reaching branches?	if yes, $n_4 = 0.100 - 0.200$

$$n_4 = \underline{\hspace{2cm}}$$

Notes:

Sinuosity/meandering factor

$$m = \underline{1.00}$$

Notes: Not applicable to floodplains.

Manning's n - Overbank

$n =$

APPENDIX D

**FORM 3 - GUIDANCE OF SELECTION FISH PASSAGE
DESIGN OPTION**

Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:

Design Species/ Life Stage	<input type="checkbox"/>	All Species
	<input type="checkbox"/>	Adult Anadromous Salmonids
	<input type="checkbox"/>	Adult Non-Anadromous Salmonids
	<input type="checkbox"/>	Juvenile Salmonids
	<input type="checkbox"/>	Native Non-Salmonids
	<input type="checkbox"/>	Non-Native Species

☐ **Active Channel Design Option** - The Active Channel Design Option is a simplified design method that is intended to size a crossing sufficiently large and embedded deep enough into the channel to allow the natural movement of bedload and formation of a stable streambed inside the culvert. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this option since with stream hydraulic characteristics within the culvert are intended to mimic the stream conditions upstream and downstream of the crossing. However, hydraulic analyses for traffic safety, hydraulic impacts, and scour are required.

Criteria for choosing option:

☐ New and replacement culvert/bridge installations

☐ Passage required for all species

☐ Proposed culver/bridge length less than 100 feet

☐ Channel slope less than 3%

☐ **Hydraulic Design Option** - The Hydraulic Design Option is a design process that matches the hydraulic performance of a culvert with the swimming abilities of a target species and age class of fish. This method targets distinct species of fish and, therefore, does not account for ecosystem requirements of non-target species.

Criteria for choosing option:

☐ New and replacement culvert/bridge installations (If retrofit installation, see Baffle or Rock Weir Design Options)

☐ Target species identified for passage

☐ Low to moderate channel slopes (less than 3%)

☐ Active channel design or stream simulation design options are not physically feasible

Retrofit Culvert/Bridge Installations

☐ **Baffle Design Option** - The Baffle Design Option is a Hydraulic Design process that is intended to increase flow depth, or to add roughness elements as a measure to reduce flow velocity within the culvert/bridge structure. Determination of the high and low fish passage design flows, water velocity, and water depth is required for this option.

☐ Retrofit culvert/bridge installation

☐ Little bedload material movement

- ☐ Existing culvert/bridge is structurally sound
- ☐ Target species identified for passage
- ☐ Low to moderate channel slopes
- ☐ Active channel design or stream simulation design options are not physically feasible

- ☐ **Rock Weir Design Option** - The Rock Weir Design Option is a Hydraulic Design process that is intended to increase flow depth, or add roughness elements as a measure to reduce flow velocity, or to increase the channel slope downstream of the culvert/bridge. Determination of the high and low fish passage design flows, water velocity, and water depth is required for this option.

- ☐ Retrofit culvert/bridge installations
- ☐ Perched condition at outlet
- ☐ Steep slope at inlet
- ☐ Target species identified for passage
- ☐ Active channel design or stream simulation design options are not physically feasible

- ☐ **Stream Simulation Design Option** - The Stream Simulation Design Option is a design process that is intended to mimic the natural stream processes within a culvert. Fish passage, sediment transport, flood and debris conveyance within the crossing are intended to function as they would in a natural channel. Determination of the high and low fish passage design flows, water velocity, and water depth is not required for this options since the stream hydraulic characteristics within the culvert are designed to mimic the stream conditions upstream and downstream of the crossing.

Criteria for choosing option:

- ☐ New and replacement culvert/bridge installations
- ☐ Passage required for all species
- ☐ Culvert/bridge length greater than 100 feet
- ☐ Channel width should be less than 20 feet
- ☐ Minimum culvert/bridge width no less than 6 feet
- ☐ Culvert/bridge slope does not greatly exceed slope of natural channel, slopes of 6 % or less
- ☐ Narrow stream valleys

Selected Design Option:

Basis for Selection:

Seek Agency Approval: ☐ Yes ☐ No

APPENDIX D

**FORM 4 - GUIDANCE ON METHODOLOGY FOR
HYDROLOGIC ANALYSIS**

Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:

Summary of Methods for Estimating Peak Design Discharges for Use in Hydraulic Analysis		
Ungaged Streams		
<input type="checkbox"/> Regional Regression ^{3, 4}		
<u>Data Requirements</u>	<u>Limitations</u>	<u>Guidance</u>
<ul style="list-style-type: none"> Drainage area Mean annual precipitation Altitude index 	<ul style="list-style-type: none"> Peak discharge value for flow under natural conditions unaffected by urban development and little or no regulation by lakes or reservoirs Ungaged channel 	The most recently published USGS report for estimating peak discharges may be used. The user should exercise caution to ensure that the reports are used only for the conditions and locations for which they are recommended.

Rainfall-Runoff Models		
<input type="checkbox"/> NRCS (TR 55) ⁵		
<u>Data Requirements</u>	<u>Limitations</u>	<u>Guidance</u>
<ul style="list-style-type: none"> 24-hour Rainfall Rainfall distribution Runoff curve number Concentration time Drainage area 	<ul style="list-style-type: none"> Small or midsize catchment (<8 km²) Maximum of 10 subwatersheds Concentration time range from 0.1-10 hour (tabular hydrograph method limit <2 hour) Runoff is overland and channel flow Simplified channel routing Negligible channel storage 	TR-55 focuses on small urban and urbanizing watersheds.

<input type="checkbox"/> HEC-1/HEC-HMS ^{6, 7} (SCS Dimensionless, Snyder Unit, Clark Unit Hydrographs)		
<u>Data Requirements</u>	<u>Limitations</u>	<u>Guidance</u>
<ul style="list-style-type: none"> Watershed/subbasin parameters Precipitation depth, duration, frequency, and distribution Precipitation losses Unit hydrograph parameters Streamflow routing and diversion parameters 	<ul style="list-style-type: none"> Simulations are limited to a single storm event Streamflow routing is performed by hydrologic routing methods and is therefore not appropriate for unsteady state routing conditions. 	Can be used for watersheds which are: small or large, simple or complex, and developed or undeveloped.

¹ Caltrans Highway Design Manual, Chapter 810 Hydrology, Topic 819 Estimating Design Discharge² FEMA Guidelines and Specifications, Appendix C, Section C.1³ USGS Water-Resources Investigation 77-21 (Magnitude and Frequency of Floods in California)⁴ USGS Open-File Report 93-419 (Methods for Estimating Magnitude and Frequency of floods in the Southwestern United States)⁵ United States Department of Agriculture, Natural Resources Conservation Service, Urban Hydrology for Small Watersheds Technical Release 55, June 1986. http://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf⁶ HEC-1 User's Manual⁷ HEC-HMS User's Manual⁸ Bulletin 17B

GAGED STREAMS

☐ Statistical Methods⁸

<u>Data Requirements</u>	<u>Limitations</u>	<u>Guidance</u>
<ul style="list-style-type: none"> 10 or more years of gaged flood records 	<ul style="list-style-type: none"> Gage data is usually only available for midsized and large catchments Appropriate station and/or generalized skew coefficient relationship applied 	For watersheds with less than 50 years of record, compare with results of appropriate USGS regional regression equations. For watersheds with less than 25 years of record, compare with results of appropriate USGS regional regression equations and/or HEC-1/HEC-HMS model results.

☐ Basin Transfer of Gage Data

<u>Data Requirements</u>	<u>Limitations</u>	<u>Guidance</u>
<ul style="list-style-type: none"> Discharge and area for gaged watershed Area for ungaged watershed 	<ul style="list-style-type: none"> Similar hydrologic characteristics Channel storage 	Must obtain approval of transfer technique from hydraulics engineer prior to use.

☐ Fish Passage Flows

<ul style="list-style-type: none"> Streamflow hydrograph Flow duration curve 		Lower and upper fish passage flows define the range of flows a culvert should contain suitable conditions for fish passage.
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Selected Hydrologic Method:

Basis for Selection:

¹ Caltrans Highway Design Manual, Chapter 810 Hydrology, Topic 819 Estimating Design Discharge² FEMA Guidelines and Specifications, Appendix C, Section C.1³ USGS Water-Resources Investigation 77-21 (Magnitude and Frequency of Floods in California)⁴ USGS Open-File Report 93-419 (Methods for Estimating Magnitude and Frequency of floods in the Southwestern United States)⁵ United States Department of Agriculture, Natural Resources Conservation Service, Urban Hydrology for Small Watersheds Technical Release 55, June 1986. ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf⁶ HEC-1 User's Manual⁷ HEC-HMS User's Manual⁸ Bulletin 17B

Verify Reasonableness and Recommended Peak Discharges

Source	50% Annual Probability (2-Year Flood Event) (cfs)	10% Annual Probability (10-Year Flood Event) (cfs)	4% Annual Probability (25-Year Flood Event) (cfs)	2% Annual Probability (50-Year Flood Event) (cfs)	1% Annual Probability (100-Year Flood Event) (cfs)	High Fish Passage Design Flow (cfs)	Low Fish Passage Design Flow (cfs)
Effective Study Peak Discharges							
Recommended Peak Discharges							

Hydrologic Analysis Index Attached ☐ Yes ☐ NoHydrologic Analysis Calculations Attached ☐ Yes ☐ No¹ Caltrans Highway Design Manual, Chapter 810 Hydrology, Topic 819 Estimating Design Discharge² FEMA Guidelines and Specifications, Appendix C, Section C.1³ USGS Water-Resources Investigation 77-21 (Magnitude and Frequency of Floods in California)⁴ USGS Open-File Report 93-419 (Methods for Estimating Magnitude and Frequency of floods in the Southwestern United States)⁵ United States Department of Agriculture, Natural Resources Conservation Service, Urban Hydrology for Small Watersheds Technical Release 55, June 1986. ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf⁶ HEC-1 User's Manual⁷ HEC-HMS User's Manual⁸ Bulletin 17B

HYDROLOGIC ANALYSES INDEX	FORM 4
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HYDROLOGIC ANALYSES INDEX	FORM 4
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Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:

[illegible]

APPENDIX D

**FORM 5 - GUIDANCE ON METHODOLOGY FOR
HYDRAULIC ANALYSIS**

Project Information

Computed:

Date:

Checked:

Date:

Stream Name:

County:

Route:

Postmile:

Summary of Methods for Hydraulic Analysis

☐ FHWA Design Charts☐ HY8 - Culvert Analysis or other HDS-5 Based Software☐ HEC-2 / HEC-RAS☐ Fish Xing (Pre-design assessment or post-design assessment when applicable)Is the hydraulic model used to create the effective FIRM available? ☐ Yes ☐ No

If yes, update and use this model for the hydraulic model.

Selected Method:

Basis for Selection:

Verify Reasonableness and Recommended Flows ☐ Yes ☐ NoHydraulic Analyses Index Attached ☐ Yes ☐ NoHydraulic Analysis Calculation Attached ☐ Yes ☐ No

HYDRAULIC ANALYSES INDEX	FORM 5
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HYDRAULIC ANALYSES INDEX	FORM 5
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Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:

[illegible]

APPENDIX D

FORM 6A - ACTIVE CHANNEL DESIGN OPTION

FISH PASSAGE: ACTIVE CHANNEL DESIGN OPTION

FORM 6A

Project Information

Computed:

Date:

Checked:

Date:

Stream Name:

County:

Route:

Postmile:

Hydrology Results - Peak Discharge Values

50% Annual Probability
(2-Year Flood Event)

cfs

10% Annual Probability
(10-Year Flood Event)

cfs

2% Annual Probability
(50-Year Flood Event)

cfs

1% Annual Probability
(100-Year Flood Event)

cfs

Establish Culvert Setting and Dimensions

Culvert Width - The minimum culvert width shall be equal to, or greater than, 1.5 times the average active channel width.

Average Active
Channel Width =

ft

Average Active Channel Width
X 1.5 =

ft

Culvert Width =

ft

Culvert Length - Must be less than 100 feet.

Culvert Length =

ft

Culvert Embedment - The bottom of the culvert shall be buried into the streambed not less than 20% of the culvert height at the outlet and not more than 40% of the culvert height at the inlet.

Upstream Embedment =

ft (≤ then 40% of culvert rise)

Downstream Embedment =

ft (≥ 20% of culvert rise)

Culvert Slope - The culvert shall be placed level (0% slope).

Upstream invert elevation =

ft

Downstream invert elevation =

ft

Summarize Proposed Culvert Physical Characteristics

Inlet Characteristics

Inlet Type

☐ Projecting

☐ Headwall

☐ Wingwall

☐ Flared end section

☐ Segment connection

☐ Skew Angle:

°

Barrel Characteristics

Diameter:

in

Fill height above culvert:

ft

Height/Rise:

ft

Length:

ft

FISH PASSAGE: ACTIVE CHANNEL DESIGN OPTION

FORM 6A

Width/Span: _____ ft		Number of barrels: _____	
Culvert Type	<input type="checkbox"/> Arch	<input type="checkbox"/> Box	<input type="checkbox"/> Circular
	<input type="checkbox"/> Pipe-Arch	<input type="checkbox"/> Elliptical	
Culvert Material	<input type="checkbox"/> HDPE	<input type="checkbox"/> Steel Plate Pipe	<input type="checkbox"/> Concrete Pipe
	<input type="checkbox"/> Spiral Rib / Corrugated Metal Pipe		
Horizontal alignment breaks: _____ ft		Vertical alignment breaks: _____ ft	
Outlet Characteristics			
Outlet Type	<input type="checkbox"/> Projecting	<input type="checkbox"/> Headwall	<input type="checkbox"/> Wingwall
	<input type="checkbox"/> Flared end section	<input type="checkbox"/> Segment connection	Skew Angle: _____ °
Summarize Proposed Bridge Physical Characteristics			
Bridge Physical Characteristics			
Elevation of high chord (top of road): _____ ft		Elevation of low chord: _____ ft	
Channel Lining	<input type="checkbox"/> No lining	<input type="checkbox"/> Concrete	<input type="checkbox"/> Rock
Skew Angle: _____ °		Bridge width (length): _____ ft	
Pier Characteristics (if applicable) <input type="checkbox"/>			
Number of Piers: _____ ft		Upstream cross-section starting station: _____ ft	
Pier Width: _____ ft		Downstream cross-section starting station: _____ ft	
Pier Centerline Spacing: _____ ft		Skew angle: _____ °	
Pier Shape	<input type="checkbox"/> Square nose and tail	<input type="checkbox"/> Semi-circular nose and tail	<input type="checkbox"/> 90° triangular nose and tail
	<input type="checkbox"/> Twin-cylinder piers with connecting diaphragm	<input type="checkbox"/> Twin-cylinder piers without connecting diaphragm	<input type="checkbox"/> Ten pile trestle bent
Maximum Allowable Inlet Water Surface Elevation			
Culvert			
A culvert is required to pass the 10-year peak discharge without causing pressure flow in the culvert,		Allowable WSEL: _____ ft	
And shall not be greater than 50% of the culvert height or diameter above the top of the culvert inlet for the 100-Year peak flood.		Allowable WSEL: _____ ft	

Bridge

A bridge is required to pass the 50-year peak discharge with freeboard, vertical clearance between the lowest structural member and the water surface elevation,

Allowable WSEL: _____ ft

While passing the 100-year peak or design discharge under low chord of bridge.

Allowable WSEL: _____ ft

Establish Allowable Hydraulic Impacts

Is the crossing located within a floodplain as designated by the Federal Emergency Management Agency or another responsible state or local agency?
☐ Yes ☐ No

If yes, establish allowable hydraulic impacts and hydraulic design requirements with the appropriate agency. Attach results.

Will the project result in the increase capacity of an existing crossing? ☐ Yes ☐ No

If yes, will it significantly increase downstream peak flows due to the reduced upstream attenuation? ☐ Yes ☐ No

If yes, consult District Hydraulics. Further analysis may be needed.

Will the project result in a reduction in flow area for the 100-year peak discharge? ☐ Yes ☐ No

If yes, establish the allowable increase in upstream water surface elevation and establish how far upstream the increased water surface may extend.

Develop and run Hydraulic Models to compute water surface elevations, flow depths, and channel velocities for the 2-, 10-, 50-, and 100-year peak or design discharges reflecting existing and project conditions. ☐ Yes ☐ No

Evaluate computed water surface elevations, flow depths, and channel velocities. ☐ Yes ☐ No

Water surface elevation at inlet for the 10-year peak discharge: _____ ft

Does the water surface elevation exceed the allowable elevation? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Maximum Culvert and Channel velocities at inlet and outlet transition for the peak or design discharge:

Range of velocities for Inlet transition:	ft/s	to	ft/s
---	------	----	------

Range of velocities for Culvert portion:	ft/s	to	ft/s
--	------	----	------

Range of velocities for Outlet Transition:	ft/s	to	ft/s
--	------	----	------

Do the velocities exceed the permissible scour velocities? ☐ Yes ☐ No

If yes, revise design to reduce velocities and rerun hydraulic analyses to verify, or design erosion protection.

Comparison between existing and project future condition water surface elevations for the 10-Year and 100-Year peak flow:

Cross-Section	10-Yr WSEL	10-Yr WSEL	Difference	100-Year WSEL	100-Year WSEL	Difference
	Existing	Future	(ft)	Existing	Future	(ft)

FISH PASSAGE: ACTIVE CHANNEL DESIGN OPTION

FORM 6A

	Conditions (ft)	Conditions (ft)		Conditions (ft)	Conditions (ft)	
1						
2						
3						
4						
If WSELs increase, does the increase exceed the maximum elevation? <input type="checkbox"/> Yes <input type="checkbox"/> No				Maximum elevation: _____ ft		
If yes, revise the design and rerun hydraulic analyses to verify.						
If WSELs decrease, does it appear that the attenuation of peak flow will significantly change? <input type="checkbox"/> Yes <input type="checkbox"/> No						
If yes, evaluate to determine if downstream hydraulic impacts are significant and modify design as appropriate.						
Proposed Plan and Profile Drawing Attached <input type="checkbox"/> Yes <input type="checkbox"/> No						
Hydraulic Analysis Index Sheet Attached <input type="checkbox"/> Yes <input type="checkbox"/> No						

APPENDIX D
FORM 6B - HYDRAULIC DESIGN OPTION

FISH PASSAGE: HYDRAULIC DESIGN OPTION

FORM 6B

Project Information

Computed:

Date:

Checked:

Date:

Stream Name:

County:

Route:

Postmile:

General Considerations

Hydraulic controls (e.g. boulders weirs, log sills, etc.) in the channel upstream and/or downstream of a crossing can be used to provide a continuous low flow path through the crossing and stream reach. They can be used to facilitate fish passage by establishing the following desirable conditions: control depth and water velocity within the crossing, concentrate low flows, provide resting pools upstream and downstream of the crossing, and control erosion of the streambed and banks.

Baffles or weirs shall not be used in the design of new or replacement culverts in order to meet the hydraulic design criteria.

The following Adverse Hydraulic Conditions are generally considered to be detrimental to efficient fish passage and should be avoided. The degree to which they impede fish passage depends upon the magnitude of the condition. Crossing designed by the Hydraulic Design Option should be evaluated for the following conditions at high design flow for fish passage: Super critical flow, Hydraulic jumps, Highly turbulent conditions, and Abrupt changes in water surface elevation in inlet and outlet.

Hydrology Results - Peak Discharge Values

50% Annual Probability (2-Year Flood Event)	cfs	10% Annual Probability (10-Year Flood Event)	cfs
2% Annual Probability (50-Year Flood Event)	cfs	1% Annual Probability (100-Year Flood Event)	cfs
High Fish Passage Design Flow	cfs	Low Fish Passage Design Flow	cfs

Estabish Proposed Culvert Settings and Dimensions

Culvert Width - The minimum culvert width shall be 3 feet.

Proposed Culvert Width: ft

Culvert Embedment - Where physically possible, the bottom of the culvert shall be buried into the streambed a minimum of 20% of the height of the culvert below the elevation of the tailwater control point downstream of the culvert. The minimum embedment should be at least 1 foot. Where physical conditions preclude embedment, the hydraulic drop at the outlet of a culvert shall not exceed the limits specified.

Upstream Embedment: ft (≥ 1 foot)

Downstream Embedment: ft (≥ 20% of culvert rise and ≥ 1 foot)

Culvert Slope - The culvert slope shall not exceed the slope of the stream through the reach in which the crossing is being placed. If embedment of the culvert is not possible, the maximum slope shall not exceed 0.5%.

Upstream invert elevation: ft (NGVD 29 or NAVD 88)

Downstream invert elevation: ft (NGVD 29 or NAVD 88)

Summarize Proposed Culvert Physical Characteristics

Inlet Characteristics

Inlet Type	<input type="checkbox"/> Projecting	<input type="checkbox"/> Headwall	<input type="checkbox"/> Wingwall
	<input type="checkbox"/> Flared end section	<input type="checkbox"/> Segment connection	<input type="checkbox"/> Skew Angle: °

FISH PASSAGE: HYDRAULIC DESIGN OPTION

FORM 6B

Barrel Characteristics			
Diameter:		in	Fill height above culvert:
Height/Rise:		ft	Length:
Width/Span:		ft	Number of barrels:
Culvert Type	<input type="checkbox"/> Arch <input type="checkbox"/> Box <input type="checkbox"/> Circular		
	<input type="checkbox"/> Pipe-Arch <input type="checkbox"/> Elliptical		
Culvert Material	<input type="checkbox"/> HDPE <input type="checkbox"/> Steel Plate Pipe <input type="checkbox"/> Concrete Pipe		
	<input type="checkbox"/> Spiral Rib / Corrugated Metal Pipe		
Horizontal alignment breaks:		ft	Vertical alignment breaks:
Outlet Characteristics			
Outlet Type	<input type="checkbox"/> Projecting <input type="checkbox"/> Headwall <input type="checkbox"/> Wingwall		
	<input type="checkbox"/> Flared end section <input type="checkbox"/> Segment connection Skew Angle:		
Summarize Proposed Bridge Physical Characteristics			
Bridge Physical Characteristics			
Elevation of high chord (top of road):		ft	Elevation of low chord:
Channel Lining	<input type="checkbox"/> No lining <input type="checkbox"/> Concrete <input type="checkbox"/> Rock <input type="checkbox"/> Other		
Skew Angle:		°	Bridge width (length):
Pier Characteristics (if applicable) <input type="checkbox"/>			
Number of Piers:		ft	Upstream cross-section starting station:
Pier Width:		ft	Downstream cross-section starting station:
Pier Centerline Spacing:		ft	Skew angle:
Pier Shape	<input type="checkbox"/> Square nose and tail <input type="checkbox"/> Semi-circular nose and tail <input type="checkbox"/> 90° triangular nose and tail		
	<input type="checkbox"/> Twin-cylinder piers with connecting diaphragm <input type="checkbox"/> Twin-cylinder piers without connecting diaphragm <input type="checkbox"/> Ten pile trestle bent		
Establish High Design Flow for Fish Passage - Depending on species, develop high design flows:			
Species/Life Stage	Percent Annual Exceedance Flow	Percentage of 2-Yr Recurrence Interval Flow	Design Flows (cfs)
<input type="checkbox"/> Adult Anadromous Salmonids	1%	50%	

FISH PASSAGE: HYDRAULIC DESIGN OPTION
FORM 6B

<input type="checkbox"/> Adult Non-Anadromous Salmonids	5%	30%	
<input type="checkbox"/> Juvenile Salmonids	10%	10%	
<input type="checkbox"/> Native Non-Salmonids	5%	30%	
<input type="checkbox"/> Non-Native Species	10%	10%	

Establish Low Design Flow for Fish Passage - Depending on species, develop low design flows:

Species/Life Stage	Percent Annual Exceedance Flow	Alternate Minimum Flow (cfs)	Design Flow (cfs)
<input type="checkbox"/> Adult Anadromous Salmonids	50%	3	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	90%	2	
<input type="checkbox"/> Juvenile Salmonids	95%	1	
<input type="checkbox"/> Native Non-Salmonids	90%	1	
<input type="checkbox"/> Non-Native Species	90%	1	

Establish Maximum Average Water Velocity and Minimum Flow Depth in Culvert (At high design flow) - Depending on culvert length and/or species, select Maximum Average Water Velocity and Minimum Flow Depth.

Species/Life Stage	Maximum Average Water Velocity at High Fish Design Flow (ft/sec)	Minimum Flow Depth at Low Fish Design Flow (ft)
<input type="checkbox"/> Adult Anadromous Salmonids	6 (Culvert length <60 ft)	1.0
	5 (Culvert length 60-100 ft)	
	4 (Culvert length 100-200 ft)	
	3 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	4 (Culvert length <60 ft)	0.67
	4 (Culvert length 60-100 ft)	
	3 (Culvert length 100-200 ft)	
	2 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
<input type="checkbox"/> Juvenile Salmonids	1	0.5

☐ Native Non-Salmonids☐ Non-Native Species

Species specific swimming performance data is required for the use of the hydraulic design option for non-salmonids. Hydraulic design is not allowed for these species without this data.

Establish Maximum Outlet Drop

Hydraulic drops between the water surface in the culvert to the pool below the culvert should be avoided for all cases. Where fish passage is required and a hydraulic drop is unavoidable, it's magnitude should be evaluated for both high design flow and low design flow and shall not exceed the values shown below. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth shall be provided.

Species/Life Stage	Maximum Drop (ft)
<input type="checkbox"/> Adult Anadromous Salmonids	1
<input type="checkbox"/> Adult Non-Anadromous Salmonids	1
<input type="checkbox"/> Juvenile Salmonids	0.5
<input type="checkbox"/> Native Non-Salmonids	Where fish passage is required for native non-salmonids no hydraulic drop shall be allowed at the culvert outlet unless data is presented which will establish the leaping ability and leaping behavior of the target species of fish.
<input type="checkbox"/> Non-Native Species	

Maximum Allowable Inlet Water Surface ElevationCulvert ☐

A culvert is required to pass the 10-year peak discharge without causing pressure flow in the culvert,

Allowable WSEL:

ft

And shall not be greater than 50% of the culvert height or diameter above the top of the culvert inlet for the 100-Year peak flood.

Allowable WSEL:

ft

Bridge ☐

A bridge is required to pass the 50-year peak discharge with freeboard, vertical clearance between the lowest structural member and the water surface elevation,

Allowable WSEL:

ft

While passing the 100-year peak or design discharge under low chord of the bridge.

Allowable WSEL:

ft

Establish Allowable Hydraulic Impacts

Is the crossing located within a floodplain as designated by the Federal Emergency Management Agency or another responsible state or local agency?

☐ Yes ☐ No

If yes, establish allowable hydraulic impacts and hydraulic design requirements with the appropriate agency. Attach results.

Will the project result in the increase capacity of an existing crossing? ☐ Yes ☐ No

If yes, will it significantly increase downstream peak flows due to the reduced upstream attenuation? ☐ Yes ☐ No

If yes, consult District Hydraulics. Further analysis may be needed.

FISH PASSAGE: HYDRAULIC DESIGN OPTION

FORM 6B

Will the project result in a reduction in flow area for the 100-year peak discharge? ☐ Yes ☐ No

If yes, establish the allowable increase in upstream water surface elevation and establish how far upstream the increased water surface may extend.

Develop and run Hydraulic Models to compute water surface elevations, flow depths, and channel velocities for the low fish passage design flow, the high fish passage design flow and for the 2-, 10-, 50-, and 100-year peak or design discharges reflecting existing and project conditions.

☐ Yes ☐ No

Evaluate computed water surface elevations, flow depths, and channel velocities: ☐ Yes ☐ No

Maximum average velocity in culvert at high fish design flow: ft/s

Does the velocity exceed the maximum allowable for the culvert length and design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Minimum flow depth in culvert at low fish design flow: ft

Does the depth equal or not exceed the minimum allowable for the culvert length and design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Drop between the water surface elevation in the culvert and the outlet channel for:

High Fish Passage Flow: ft	Low Fish Passage Flow: ft
---	--

Does the drop between the water surface in the culvert and the outlet channel at high or low design fish flows exceed the maximum allowable for the design species? ☐ Yes ☐ No

If yes, modify design to avoid a drop if possible. If a drop is unavoidable modify design to meet criteria and provide a jump pool at least two feet in depth. Rerun hydraulic analyses to verify.

Water Surface elevation at inlet for the 10-year peak discharge:

Does the water surface elevation exceed the allowable? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Maximum Culvert and Channel velocities at inlet and outlet transition for the peak or design discharge:

Range of velocities for Inlet transition:	ft/s	to	ft/s
---	------	----	------

Range of velocities for Culvert portion:	ft/s	to	ft/s
--	------	----	------

Range of velocities for Outlet Transition:	ft/s	to	ft/s
--	------	----	------

Do the velocities exceed the permissible scour velocities? ☐ Yes ☐ No

If yes, revise design to reduce velocities and rerun hydraulic analyses to verify, or design erosion protection.

Comparison between existing and project future condition water surface elevations for the 10-Year and 100-Year peak flow:

Cross-Section	10-Yr WSEL	10-Yr WSEL	WSEL Difference	100-Year WSEL	100-Year WSEL	WSEL Difference
	Existing	Future	(ft)	Existing	Future	(ft)

FISH PASSAGE: HYDRAULIC DESIGN OPTION

FORM 6B

	Conditions (ft)	Conditions (ft)		Conditions (ft)	Conditions (ft)	
1						
2						
3						
4						

If WSELs increase, does the increase exceed the maximum elevation? ☐ Yes ☐ No Maximum elevation: _____ ft

If yes, revise the design and rerun hydraulic analyses to verify.

If WSELs decrease, does it appear that the attenuation of peak flow will significantly change? ☐ Yes ☐ No

If yes, evaluate to determine if downstream hydraulic impacts are significant and modify design as appropriate.

Proposed Plan and Profile Drawing Attached ☐ Yes ☐ No

Hydraulic Analysis Index Sheet Attached ☐ Yes ☐ No

APPENDIX D

FORM 6C - STREAM SIMULATION DESIGN OPTION

FISH PASSAGE: STREAM SIMULATION DESIGN OPTION

FORM 6C

Project Information

Computed:

Date:

Checked:

Date:

Stream Name:

County:

Route:

Postmile:

General Considerations

The **Stream Simulation** method strives to result in the same passage conditions within the culvert as those seen in the selected reference reach, to the extent practical. The Stream Simulation process includes these four steps: 1) Develop long profile and define the reference reach, 2) Establish proposed structure settings and dimensions, 3) Design bed material and shape, and 4) Check bed stability.

Hydrology Results - Peak Discharge Values

50% Annual Probability
(2-Year Flood Event)

cfs

10% Annual Probability
(10-Year Flood Event)

cfs

4% Annual Probability
(25-Year Flood Event)

cfs

2% Annual Probability
(50-Year Flood Event)

cfs

1% Annual Probability
(100-Year Flood Event)

cfs

Develop Long Profile and Define the Reference Reach

Attach channel profile sheet. ☐ Yes ☐ No

Identify reference reach on long profile with characteristics that will be appropriate for the replacement culvert. ☐ Yes ☐ No

Identify channel type and key features that vary depending on the bed mobility. ☐ Yes ☐ No

Identify location of bed material samples on profile. ☐ Yes ☐ No

Identify typical channel cross-sections. ☐ Yes ☐ No

Identify channel characteristics and processes on long profile. ☐ Yes ☐ No

Plot stream/culvert profile or range of profiles for consideration. ☐ Yes ☐ No

Illustrate the typical reference reach cross-section:

Bankfull Channel: The channel defined by the bankfull discharge, which is the discharge that fills a stable alluvial channel up to the elevation of the active floodplain. Identification of the bankfull channel should be based on the determination of the minimum channel width to depth ratio determined from cross sectional measurements of stable channel reaches upstream and downstream of the proposed culvert location.

Bankfull channel width = _____ ft

Estabilsh Proposed Culvert Settings and Dimensions

Culvert Width: Culvert width is the width needed to span the bankfull channel. If permanent banklines are constructed of rock, adequate culvert width must be provided to span the bed plus the size of the rock on both banks. For an initial estimate of the minimum culvert width, add twice the diameter of the largest material in the bed to the bankfull width. A stability analysis might show that other bed material is needed.

Culvert Width = _____ ft

Culvert Length: Culvert length must be greater than 100 feet

Culvert Length = _____ ft

Culvert Embedment: A circular culvert embedded into the streambed no less than 30% but no more than 50% of its rise is a good practical guide.

Upstream embedment = _____ ft Downstream embedment = _____ ft

Culvert Slope Culvert slope does not greatly exceed slope of natural channel, slopes of 6% or less

Upstream invert elevation = _____ ft (NGVD 29 or NAVD 88) Downstream invert elevation = _____ ft (NGVD 29 or NAVD 88)

Summarize Proposed Culvert Physical Characteristics

Inlet Characteristics

Inlet Type	<input type="checkbox"/> Projecting	<input type="checkbox"/> Headwall	<input type="checkbox"/> Wingwall
	<input type="checkbox"/> Flared end section	<input type="checkbox"/> Segment connection	<input type="checkbox"/> Skew Angle: _____ °

Barrel Characteristics

Diameter: _____ in Fill height above culvert: _____ ft

Height/Rise: _____ ft Length: _____ ft

Width/Span: _____ ft Number of barrels: _____

Culvert Type	<input type="checkbox"/> Arch	<input type="checkbox"/> Box	<input type="checkbox"/> Circular
	<input type="checkbox"/> Pipe-Arch	<input type="checkbox"/> Elliptical	

Culvert Material	<input type="checkbox"/> HDPE <input type="checkbox"/> Steel Plate Pipe <input type="checkbox"/> Concrete Pipe <input type="checkbox"/> Spiral Rib / Corrugated Metal Pipe			
Horizontal alignment breaks: _____ ft		Vertical alignment breaks: _____ ft		
Outlet Characteristics				
Outlet Type	<input type="checkbox"/> Projecting <input type="checkbox"/> Flared end section	<input type="checkbox"/> Headwall <input type="checkbox"/> Segment connection	<input type="checkbox"/> Wingwall Skew Angle: _____ °	
Summarize Proposed Bridge Physical Characteristics				
Bridge Physical Characteristics				
Elevation of high chord (top of road): _____ ft (NGVD 29 or NAVD 88)		Elevation of low chord: _____ ft (NGVD 29 or NAVD 88)		
Channel Lining	<input type="checkbox"/> No lining	<input type="checkbox"/> Concrete	<input type="checkbox"/> Rock	<input type="checkbox"/> Other
Pier Characteristics (if applicable) <input type="checkbox"/>				
Number of Piers: _____ ft		Upstream cross-section starting station: _____ ft		
Pier Width: _____ ft		Downstream cross-section starting station: _____ ft		
Pier Centerline Spacing: _____ ft		Skew angle: _____ °		
Pier Shape	<input type="checkbox"/> Square nose and tail <input type="checkbox"/> Semi-circular nose and tail <input type="checkbox"/> 90° triangular nose and tail <input type="checkbox"/> Twin-cylinder piers with connecting diaphragm <input type="checkbox"/> Twin-cylinder piers without connecting diaphragm <input type="checkbox"/> Ten pile trestle bent			
Define Bed Material and Shape				
Create reference grain-size distribution curve from reference reach material. <input type="checkbox"/> Yes <input type="checkbox"/> No				
Bed Stability Analysis				
1. Establish bed design flows		25-Year design storm, Q = _____ cfs		
2. Determine average water depth in culvert		Culvert inlet water depth, y = _____ ft		
		Culvert outlet water depth, y = _____ ft		

	Average water depth, $y =$	ft
3. Determine average water velocity in culvert	Culvert inlet velocity, $V_c =$	ft/s
	Culvert outlet velocity, $V_c =$	ft/s
	Average culvert velocity, $V_c =$	ft/s
4) Solve the bed stability equation by calculating D_{50} using Laursen's Equation.		
Solve Laursen's equation for Culvert bed material D_{50} Where V_c is critical velocity above which bed material of size D and smaller will be transported, (ft/s), y is average depth of flow within the culvert structure, (ft), and D_{50} is particle size in a mixture of which 50 percent are smaller, (ft).	$D_{50} = (V_c / 11.17y^{1/6})^3$	ft
5. Is the calculated D_{50} equal to or less than the reference reach D_{50} ? <input type="checkbox"/> Greater than or equal to <input type="checkbox"/> Less than		
If greater than or equal to, use reference bed material in culvert. <input type="checkbox"/>		
If less than, adjust reference grain-size distribution curve to match calculated D_{50} . <input type="checkbox"/>		
Creek Feature Stability Analysis (ie. Rock bands, Boulder Clusters, Banklines)		
1. Establish bed design flows	25-Year design storm, $Q =$	cfs
2. Determine average water velocity in culvert	Culvert inlet velocity, $V_c =$	ft/s
	Culvert outlet velocity, $V_c =$	ft/s
	Average culvert velocity, $V_c =$	ft/s
3. Determine average field rock size diameter	Average field rock size diameter, $D_{\text{field}} =$	ft
4. Select minimum stable diameter (D_{50}) corresponding to average culvert velocity	Minimum stable diameter, $D_{50} =$	ft
5. Calculated Caltrans RSP Class rough diameter	Calculated Caltrans RSP Class rough diameter, $D_{\text{rsp}} =$	ft
If minimum stable diameter is greater than average field rock size diameter, the average field rock size diameter must be increased. If minimum stable diameter is less than the average field rock size diameter, select the corresponding RSP class rough diameter.		
6. Selected Caltrans RSP Class	Selected Caltrans RSP Class =	

Maximum Allowable Inlet Water Surface Elevation

Culvert ☐

A culvert is required to pass the 10-year peak discharge without causing pressure flow in the culvert,

Allowable WSEL:

ft

And shall not be greater than 50% of the culvert height or diameter above the top of the culvert inlet for the 100-Year peak flood.

Allowable WSEL:

ft

Bridge ☐

A bridge is required to pass the 50-year peak discharge with freeboard, vertical clearance between the lowest structural member and the water surface elevation,

Allowable WSEL:

ft

While passing the 100-year peak or design discharge under low chord of bridge.

Allowable WSEL:

ft

Establish Allowable Hydraulic Impacts

Is the crossing located within a floodplain as designated by the Federal Emergency Management Agency or another responsible state or local agency?

☐ Yes ☐ No

If yes, establish allowable hydraulic impacts and hydraulic design requirements with the appropriate agency. Attach results.

Will the project result in increase capacity of an existing crossing? ☐ Yes ☐ No

If yes, will it significantly increase downstream peak flows due to the reduced upstream attenuation? ☐ Yes ☐ No

If yes, consult District Hydraulics. Further analysis may be needed.

Will the project result in a reduction in flow area for the 100-year peak discharge? ☐ Yes ☐ No

If yes, establish the allowable increase in upstream water surface elevation and establish how far upstream the increased water surface may extend.

Develop and run Hydraulic Models to compute water surface elevations, flow depths, and channel velocities for the 2-, 10-, 50-, and 100-year peak or design discharges reflecting existing and project conditions. ☐ Yes ☐ No

Evaluate computed water surface elevations, flow depths, and channel velocities. ☐ Yes ☐ No

Water surface elevation at inlet for the 10-year peak discharge:

ft

Does the water surface elevation exceed the allowable elevation? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Maximum Culvert and Channel velocities at inlet and outlet transition for the peak or design discharge:

Range of velocities for Inlet transition:

ft/s

to

ft/s

Range of velocities for Culvert portion:

ft/s

to

ft/s

FISH PASSAGE: STREAM SIMULATION DESIGN OPTION

FORM 6C

Range of velocities for Outlet Transition: _____ ft/s to _____ ft/s

Do the velocities exceed the permissible scour velocities? ☐ Yes ☐ No

If yes, revise design to reduce velocities and rerun hydraulic analyses to verify, or design erosion protection.

Comparison between existing and project future condition water surface elevations for the 10-Year and 100-Year peak flow:

Cross-Section	10-Yr WSEL	10-Yr WSEL	Difference	100-Year WSEL	100-Year WSEL	Difference
	Existing Conditions (ft)	Future Conditions (ft)	(ft)	Existing Conditions (ft)	Future Conditions (ft)	(ft)
1						
2						
3						
4						

If WSELs increase, does the increase exceed the maximum elevation? ☐ Yes ☐ No Maximum elevation: _____ ft

If yes, revise the design and rerun hydraulic analyses to verify.

If WSELs decrease, does it appear that the attenuation of peak flow will significantly change? ☐ Yes ☐ No

If yes, evaluate to determine if downstream hydraulic impacts are significant and modify design as appropriate.

Proposed Profile Drawing Attached ☐ Yes ☐ No

Hydraulic Analysis Index Sheet Attached ☐ Yes ☐ No

Bed Stability Analysis Calculations Attached ☐ Yes ☐ No

Grain-Size Distribution Curve Attached ☐ Yes ☐ No

APPENDIX D

FORM 6D - HYDRAULIC BAFFLE DESIGN OPTION

Project Information		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:
General Considerations			
Baffles shall be used in the design retrofitted culverts or bridges in order to meet the hydraulic design criteria.			
Hydrology Results - Peak Discharge Values			
50% Annual Probability (2-Year Flood Event)	cfs	10% Annual Probability (10-Year Flood Event)	cfs
2% Annual Probability (50-Year Flood Event)	cfs	1% Annual Probability (100-Year Flood Event)	cfs
High Fish Passage Design Flow	cfs	Low Fish Passage Design Flow	cfs
Selecting Weir Coefficient, C			
1) Estimate highest possible weir coefficient for design. ¹			
Initial estimate of weir coefficient, C		ft ^{0.5} /sec	
2) Check range of head over baffle in hydraulic model.			
Does the Low Fish Passage Design depths equal or not exceed the minimum allowable depth per design species? <input type="checkbox"/> Yes <input type="checkbox"/> No			
If yes, breath of crest of weir or allowable head is inappropriate for design. Modify design to comply and re-run hydraulic analyses to verify.			
Does the High Fish Passage Design velocities over the weir and through the notch exceed the minimum allowable velocities per design species? <input type="checkbox"/> Yes <input type="checkbox"/> No			
If yes, breath of crest of weir or allowable head is inappropriate for design. Modify design to comply and re-run hydraulic analyses to verify.			
If no for both questions above, determine type of weir.			
3) Determine type of weir.			
When the thickness of the crest of a weir is more than 0.47 times the head, it is classified as a broad-crested weir. ²			
Baffle/Weir width:	ft	Head:	ft
		Head x 0.47 =	ft
<input type="checkbox"/> Broad crested weir		<input type="checkbox"/> Sharp crested weir	
		<input type="checkbox"/> Other	
4) Select a more appropriate weir for particular type of weir, C:			
Establish range of reasonable C coefficients in accordance with Hydraulic Engineering Circular 22 <input type="checkbox"/> Yes <input type="checkbox"/> No			
5) Check range of head over baffle in hydraulic model.			

¹ Hydraulic Engineering Circular 22, *Urban Drainage Design Manual*, Chapter 8 (www.fhwa.dot.gov)

² Gupta, Ram S., *Hydrology and Hydraulic Systems*, Chapter 6.

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Does the Low Fish Passage Design depths equal or not exceed the minimum allowable depth per design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Does the High Fish Passage Design velocities over the baffle and through the notch exceed the minimum allowable velocities per design species?
☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Proposed Baffle Settings and Dimensions

Baffle height: _____ ft Baffle width: _____ ft

Baffle spacing (along longitudinal axis): _____ ft Weir coefficient: _____ ft^{0.5}/sec

Summarize Retrofitted Culvert Physical Characteristics

Inlet Characteristics - Retrofitted design to inlet: ☐ Yes ☐ No

Inlet Type	<input type="checkbox"/> Projecting	<input type="checkbox"/> Headwall	<input type="checkbox"/> Wingwall
	<input type="checkbox"/> Flared end section	<input type="checkbox"/> Segment connection	<input type="checkbox"/> Skew Angle: _____ °

Barrel Characteristics - Retrofitted design to barrel: ☐ Yes ☐ No

Diameter: _____ in Fill height above culvert: _____ ft

Height/Rise: _____ ft Length: _____ ft

Width/Span: _____ ft Number of barrels: _____

Culvert Type	<input type="checkbox"/> Arch	<input type="checkbox"/> Box	<input type="checkbox"/> Circular
	<input type="checkbox"/> Pipe-Arch	<input type="checkbox"/> Elliptical	

Culvert Material	<input type="checkbox"/> HDPE	<input type="checkbox"/> Steel Plate Pipe	<input type="checkbox"/> Concrete Pipe
	<input type="checkbox"/> Spiral Rib / Corrugated Metal Pipe		

Horizontal alignment breaks: _____ ft Vertical alignment breaks: _____ ft

Outlet Characteristics - Retrofitted design to outlet: ☐ Yes ☐ No

Outlet Type	<input type="checkbox"/> Projecting	<input type="checkbox"/> Headwall	<input type="checkbox"/> Wingwall
	<input type="checkbox"/> Flared end section	<input type="checkbox"/> Segment connection	Skew Angle: _____ °

Summarize Retrofitted Bridge Physical Characteristics

Bridge Physical Characteristics Retrofitted design to bridge structure: ☐ Yes ☐ No

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Elevation of high chord (top of road):		ft	Elevation of low chord:		ft
Channel Lining	<input type="checkbox"/> No lining	<input type="checkbox"/> Concrete	<input type="checkbox"/> Rock	<input type="checkbox"/> Other	
Skew Angle:		°	Bridge width (length):		ft
Pier Characteristics (if applicable) Retrofitted design to piers: <input type="checkbox"/> Yes <input type="checkbox"/> No					
Number of Piers:		ft	Upstream cross-section starting station:		ft
Pier Width:		ft	Downstream cross-section starting station:		ft
Pier Centerline Spacing:		ft	Skew angle:		°
Pier Shape	<input type="checkbox"/> Square nose and tail <input type="checkbox"/> Semi-circular nose and tail <input type="checkbox"/> 90° triangular nose and tail <input type="checkbox"/> Twin-cylinder piers with connecting diaphragm <input type="checkbox"/> Twin-cylinder piers without connecting diaphragm <input type="checkbox"/> Ten pile trestle bent				

Establish High Design Flow for Fish Passage - Depending on species, develop high design flows:

Species/Life Stage	Percent Annual Exceedance Flow	Percentage of 2-Yr Recurrence Interval Flow	Design Flows (cfs)
<input type="checkbox"/> Adult Anadromous Salmonids	1%	50%	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	5%	30%	
<input type="checkbox"/> Juvenile Salmonids	10%	10%	
<input type="checkbox"/> Native Non-Salmonids	5%	30%	
<input type="checkbox"/> Non-Native Species	10%	10%	

Establish Low Design Flow for Fish Passage - Depending on species, develop low design flows:

Species/Life Stage	Percent Annual Exceedance Flow	Alternate Minimum Flow (cfs)	Design Flow (cfs)
<input type="checkbox"/> Adult Anadromous Salmonids	50%	3	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	90%	2	
<input type="checkbox"/> Juvenile Salmonids	95%	1	
<input type="checkbox"/> Native Non-Salmonids	90%	1	
<input type="checkbox"/> Non-Native Species	90%	1	

Establish Maximum Average Water Velocity and Minimum Flow Depth in Culvert (At high design flow) - Depending on culvert length and/or species, select Maximum Average Water Velocity and Minimum Flow Depth.

Species/Life Stage	Maximum Average Water Velocity at High Fish Design Flow (ft/sec)	Minimum Flow Depth at Low Fish Design Flow (ft)

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<input type="checkbox"/> Adult Anadromous Salmonids	6 (Culvert length <60 ft)	1.0
	5 (Culvert length 60-100 ft)	
	4 (Culvert length 100-200 ft)	
	3 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	4 (Culvert length <60 ft)	0.67
	4 (Culvert length 60-100 ft)	
	3 (Culvert length 100-200 ft)	
	2 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
<input type="checkbox"/> Juvenile Salmonids	1	0.5
<input type="checkbox"/> Native Non-Salmonids	Species specific swimming performance data is required for the use of the hydraulic design option for non-salmonids. Hydraulic design is not allowed for these species without this data.	
<input type="checkbox"/> Non-Native Species		

Establish Maximum Outlet Drop

Hydraulic drops between the water surface in the culvert to the pool below the culvert should be avoided for all cases. Where fish passage is required and a hydraulic drop is unavoidable, it's magnitude should be evaluated for both high design flow and low design flow and shall not exceed the values shown below. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth shall be provided.

Species/Life Stage	Maximum Drop (ft)
<input type="checkbox"/> Adult Anadromous Salmonids	1
<input type="checkbox"/> Adult Non-Anadromous Salmonids	1
<input type="checkbox"/> Juvenile Salmonids	0.5
<input type="checkbox"/> Native Non-Salmonids	Where fish passage is required for native non-salmonids no hydraulic drop shall be allowed at the culvert outlet unless data is presented which will establish the leaping ability and leaping behavior of the target species of fish.
<input type="checkbox"/> Non-Native Species	

Maximum Allowable Inlet Water Surface Elevation

 Culvert ☐

A culvert is required to pass the 10-year peak

Allowable WSEL:

ft

FISH PASSAGE: HYDRAULIC BAFFLE DESIGN OPTION**FORM 6D**

discharge without causing pressure flow in the culvert,

And shall not be greater than 50% of the culvert height or diameter above the top of the culvert inlet for the 100-Year peak flood.

Allowable WSEL:

ft

Bridge ☐

A bridge is required to pass the 50-year peak discharge with freeboard, vertical clearance between the lowest structural member and the water surface elevation,

Allowable WSEL:

ft

While passing the 100-year peak or design discharge under low chord of the bridge.

Allowable WSEL:

ft

Establish Allowable Hydraulic Impacts

Is the crossing located within a floodplain as designated by the Federal Emergency Management Agency or another responsible state or local agency?

☐ Yes ☐ No

If yes, establish allowable hydraulic impacts and hydraulic design requirements with the appropriate agency. Attach results.

Will the project result in the increase capacity of an existing crossing? ☐ Yes ☐ NoIf yes, will it significantly increase downstream peak flows due to the reduced upstream attenuation? ☐ Yes ☐ No

If yes, consult District Hydraulics. Further analysis may be needed.

Will the project result in a reduction in flow area for the 100-year peak discharge? ☐ Yes ☐ No

If yes, establish the allowable increase in upstream water surface elevation and establish how far upstream the increased water surface may extend.

Develop and run Hydraulic Models to compute water surface elevations, flow depths, and channel velocities for the low fish passage design flow, the high fish passage design flow and for the 2-, 10-, 50-, and 100-year peak or design discharges reflecting existing and project conditions.☐ Yes ☐ NoEvaluate computed water surface elevations, flow depths, and channel velocities: ☐ Yes ☐ No**Maximum average velocity in culvert at high fish design flow:**

ft/s

Does the velocity exceed the maximum allowable for the culvert length and design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Minimum flow depth in culvert at low fish design flow:

ft

Does the depth equal or not exceed the minimum allowable for the culvert length and design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Drop between the water surface elevation in the culvert and the outlet channel for:

FISH PASSAGE: HYDRAULIC BAFFLE DESIGN OPTION

FORM 6D

High Fish Passage Flow: ft Low Fish Passage Flow: ft

Does the drop between the water surface in the culvert and the outlet channel at high or low design fish flows exceed the maximum allowable for the design species? ☐ Yes ☐ No

If yes, modify design to avoid a drop if possible. If a drop is unavoidable modify design to meet criteria and provide a jump pool at least two feet in depth. Rerun hydraulic analyses to verify.

Water Surface elevation at inlet for the 10-year peak discharge: ft

Does the water surface elevation exceed the allowable? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Maximum Culvert and Channel velocities at inlet and outlet transition for the peak or design discharge:

Range of velocities for Inlet transition: ft/s to ft/s

Range of velocities for Culvert portion: ft/s to ft/s

Range of velocities for Outlet Transition: ft/s to ft/s

Do the velocities exceed the permissible scour velocities? ☐ Yes ☐ No

If yes, revise design to reduce velocities and rerun hydraulic analyses to verify, or design erosion protection.

Comparison between existing and project future condition water surface elevations for the 10-Year and 100-Year peak flow:

Cross-Section	10-Yr WSEL	10-Yr WSEL	WSEL Difference	100-Year WSEL	100-Year WSEL	WSEL Difference
	Existing Conditions (ft)	Future Conditions (ft)	(ft)	Existing Conditions (ft)	Future Conditions (ft)	(ft)
1						
2						
3						
4						

If WSELs increase, does the increase exceed the maximum elevation? ☐ Yes ☐ No Maximum elevation: ft

If yes, revise the design and rerun hydraulic analyses to verify.

If WSELs decrease, does it appear that the attenuation of peak flow will significantly change? ☐ Yes ☐ No

If yes, evaluate to determine if downstream hydraulic impacts are significant and modify design as appropriate.

Proposed Plan and Profile Drawing Attached ☐ Yes ☐ No

Hydraulic Analysis Index Sheet Attached ☐ Yes ☐ No

APPENDIX D

FORM 6E - HYDRAULIC ROCK WEIR DESIGN OPTION

FISH PASSAGE: HYDRAULIC ROCK WEIR DESIGN OPTION

FORM 6E

Project Information

		Computed:	Date:
		Checked:	Date:
Stream Name:	County:	Route:	Postmile:

General Considerations

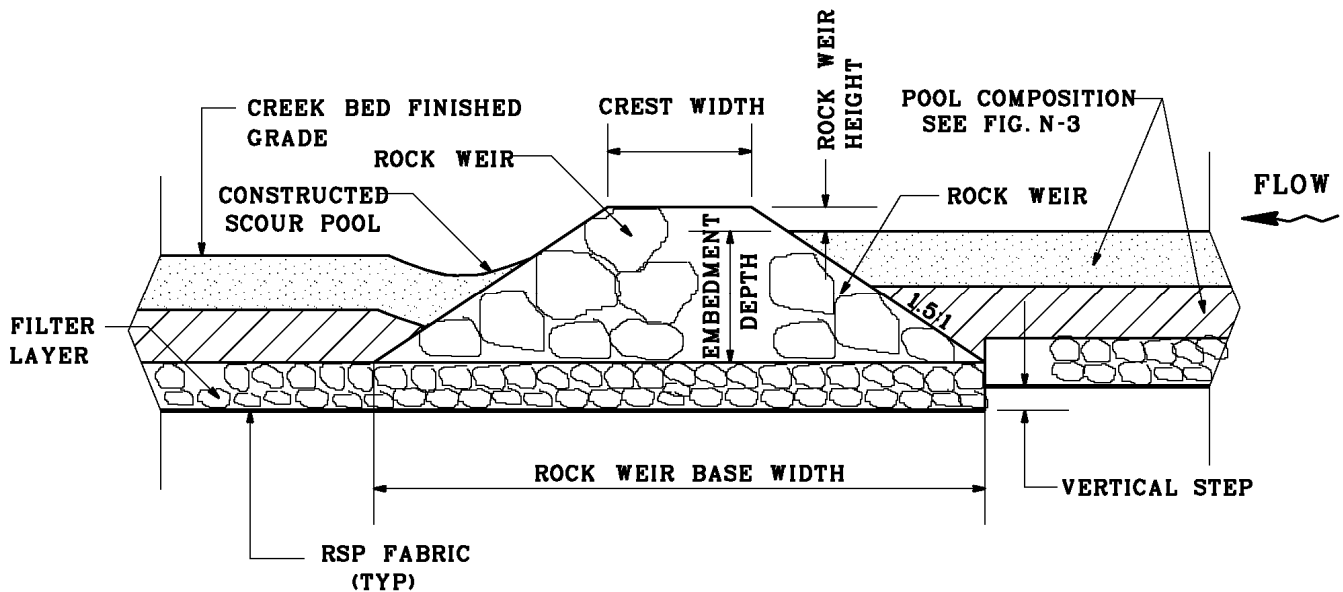
Rock weirs shall be used in the design of retrofitted culverts in order to meet the hydraulic design criteria.

Hydrology Results - Peak Discharge Values

50% Annual Probability (2-Year Flood Event)	cfs	10% Annual Probability (10-Year Flood Event)	cfs
2% Annual Probability (50-Year Flood Event)	cfs	1% Annual Probability (100-Year Flood Event)	cfs
High Fish Passage Design Flow	cfs	Low Fish Passage Design Flow	cfs

Determine Rock Weir Dimensions

Rock size (RSP class):	Embedment depth:	ft
Crest width:	Height:	ft
Side slope:	Base width:	ft
Spacing:	ft	



Rock Weir Profile

Determine Step-Pool Layers and Thickness

Tsp:	ft
Rock weir backfill thickness (1/2 Tsp):	ft

Native bed: ☐ Yes ☐ No

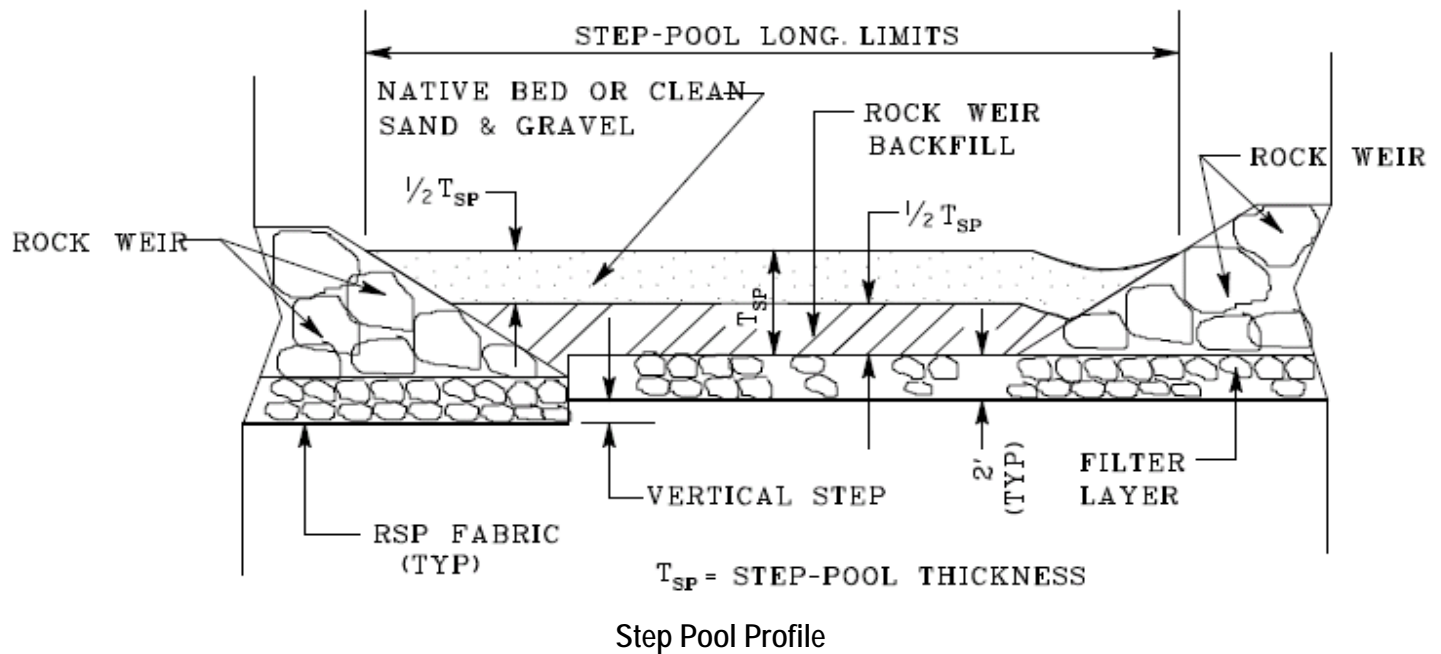
Thickness (if applicable):

ft

Clean sand and gravel: ☐ Yes ☐ No

Thickness (if applicable):

ft

**Design Bank Revetment**RSP revetment: ☐ Yes ☐ NoCombined RSP and vegetative revetment: ☐ Yes ☐ No

If yes, contact District Hydraulics Engineer and District Landscape Architect to coordinate design.

Parallel flow: ☐ Yes ☐ NoImpinging flow: ☐ Yes ☐ No

If yes, apply 1.33 factor to average stream velocity.

Bank slope (α):

°

50-year average stream velocity:

ft/s

Design velocity:

ft

50-year flow depth:

ft

Field contributing features (i.e. high water marks):

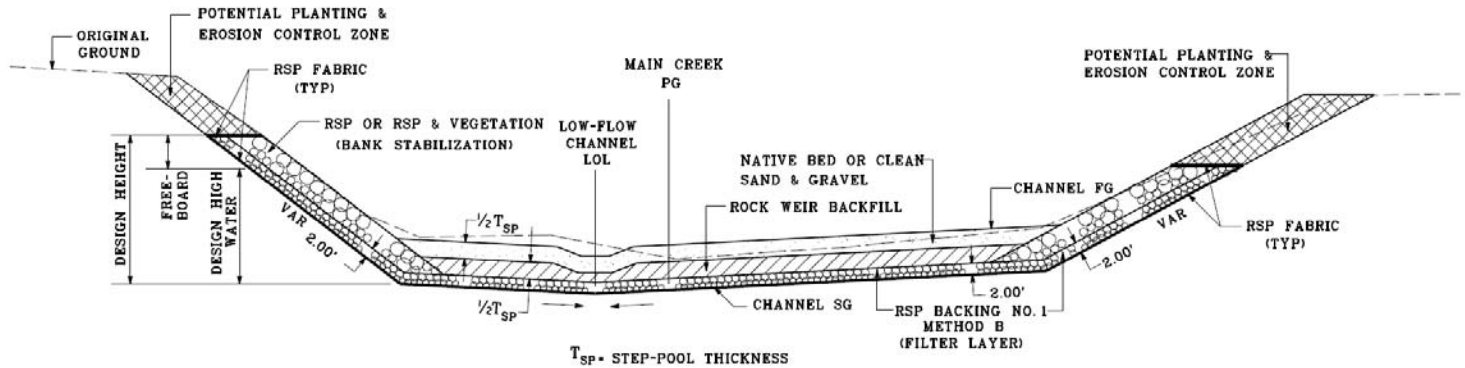
Freeboard:

ft

Design height: _____ ft

RSP class: _____

RSP thickness: _____ ft



Step Pool Cross Section

Selecting Weir Coefficient, C

1) Estimate highest possible weir coefficient for broad crested weir design.¹Initial estimate of broad crested weir coefficient, C _____ ft^{0.5}/sec

2) Check range of head over baffle in hydraulic model.

Does the Low Fish Passage Design depths equal or not exceed the minimum allowable depth per design species? ☐ Yes ☐ No

If yes, breadth of crest of weir or allowable head is inappropriate for design. Modify design to comply and re-run hydraulic analyses to verify.

Does the High Fish Passage Design velocities over the weir and through the notch exceed the minimum allowable velocities per design species?
☐ Yes ☐ No

If yes, breadth of crest of weir or allowable head is inappropriate for design. Modify design to comply and re-run hydraulic analyses to verify.

If no for both questions above, select a more appropriate broad-crested weir coefficient, C.

3) Select a more appropriate broad-crested weir coefficient, C:

Establish range of reasonable C coefficients in accordance with Hydraulic Engineering Circular 22, Urban Drainage Design Manual ☐ Yes ☐ No

4) Check range of head over baffle in hydraulic model.

Does the Low Fish Passage Design depths equal or not exceed the minimum allowable depth per design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

¹ Hydraulic Engineering Circular 22, *Urban Drainage Design Manual*, Chapter 8 (www.fhwa.dot.gov)

Does the High Fish Passage Design velocities over the baffle and through the notch exceed the minimum allowable velocities per design species?

☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

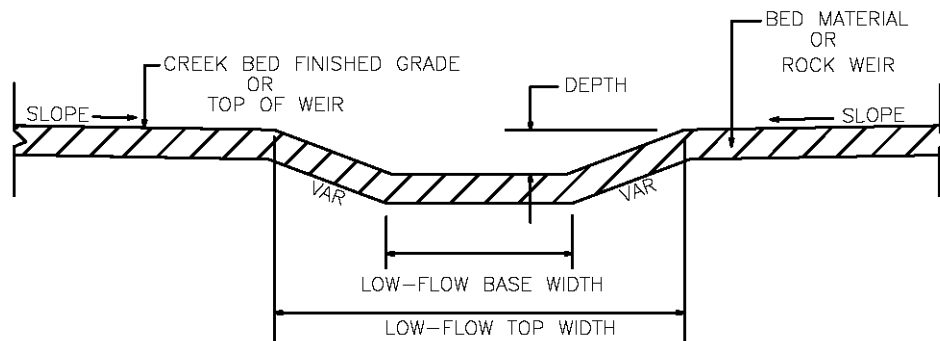
Modeled broad-crested weir coefficient:

ft^{0.5}/sec

Determine Rock Weir Low-Flow Notch/Channel Dimensions

Base Width: _____ ft Top Width: _____ ft

Depth: _____ ft



Low Flow Notch / Channel

Summarize Retrofitted Culvert Physical Characteristics

Inlet Characteristics - Retrofitted design to inlet: ☐ Yes ☐ No

Inlet Type

☐ Projecting

☐ Headwall

☐ Wingwall

☐ Flared end section

☐ Segment connection

☐ Skew Angle: _____ °

Barrel Characteristics - Retrofitted design to barrel: ☐ Yes ☐ No

Diameter: _____ in

Fill height above culvert: _____ ft

Height/Rise: _____ ft

Length: _____ ft

Width/Span: _____ ft

Number of barrels:

Culvert Type

☐ Arch

☐ Box

☐ Circular

☐ Pipe-Arch

☐ Elliptical

Culvert Material

☐ HDPE

☐ Steel Plate Pipe

☐ Concrete Pipe

☐ Spiral Rib / Corrugated Metal Pipe

Horizontal alignment breaks: _____ ft

Vertical alignment breaks: _____ ft

Outlet Characteristics - Retrofitted design to outlet: ☐ Yes ☐ No

Outlet Type

☐ Projecting

☐ Headwall

☐ Wingwall

☐ Flared end section

☐ Segment connection

Skew Angle:

°

Summarize Retrofitted Bridge Physical Characteristics

Bridge Physical Characteristics Retrofitted design to bridge structure: ☐ Yes ☐ No

Elevation of high chord (top of road):

ft

Elevation of low chord:

ft

Channel Lining

☐ No lining

☐ Concrete

☐ Rock

☐ Other

Skew Angle:

°

Bridge width (length):

ft

Pier Characteristics (if applicable) Retrofitted design to piers: ☐ Yes ☐ No

Number of Piers:

ft

Upstream cross-section starting station:

ft

Pier Width:

ft

Downstream cross-section starting station:

ft

Pier Centerline Spacing:

ft

Skew angle:

°

Pier Shape

☐ Square nose and tail

☐ Semi-circular nose and tail

☐ 90° triangular nose and tail

☐ Twin-cylinder piers with connecting diaphragm

☐ Twin-cylinder piers without connecting diaphragm

☐ Ten pile trestle bent

Establish High Design Flow for Fish Passage - Depending on species, develop high design flows:

Species/Life Stage	Percent Annual Exceedance Flow	Percentage of 2-Yr Recurrence Interval Flow	Design Flows (cfs)
<input type="checkbox"/> Adult Anadromous Salmonids	1%	50%	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	5%	30%	
<input type="checkbox"/> Juvenile Salmonids	10%	10%	
<input type="checkbox"/> Native Non-Salmonids	5%	30%	
<input type="checkbox"/> Non-Native Species	10%	10%	

Establish Low Design Flow for Fish Passage - Depending on species, develop low design flows:

Species/Life Stage	Percent Annual Exceedance Flow	Alternate Minimum Flow (cfs)	Design Flow (cfs)
<input type="checkbox"/> Adult Anadromous Salmonids	50%	3	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	90%	2	
<input type="checkbox"/> Juvenile Salmonids	95%	1	

FISH PASSAGE: HYDRAULIC ROCK WEIR DESIGN OPTION

FORM 6E

<input type="checkbox"/> Native Non-Salmonids	90%	1	
<input type="checkbox"/> Non-Native Species	90%	1	

Establish Maximum Average Water Velocity and Minimum Flow Depth in Culvert (At high design flow) - Depending on culvert length and/or species, select Maximum Average Water Velocity and Minimum Flow Depth.

Species/Life Stage	Maximum Average Water Velocity at High Fish Design Flow (ft/sec)	Minimum Flow Depth at Low Fish Design Flow (ft)
<input type="checkbox"/> Adult Anadromous Salmonids	6 (Culvert length <60 ft)	1.0
	5 (Culvert length 60-100 ft)	
	4 (Culvert length 100-200 ft)	
	3 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
<input type="checkbox"/> Adult Non-Anadromous Salmonids	4 (Culvert length <60 ft)	0.67
	4 (Culvert length 60-100 ft)	
	3 (Culvert length 100-200 ft)	
	2 (Culvert length 200-300 ft)	
	2 (Culvert length >300 ft)	
<input type="checkbox"/> Juvenile Salmonids	1	0.5
<input type="checkbox"/> Native Non-Salmonids	Species specific swimming performance data is required for the use of the hydraulic design option for non-salmonids. Hydraulic design is not allowed for these species without this data.	
<input type="checkbox"/> Non-Native Species		

Establish Maximum Outlet Drop

Hydraulic drops between the water surface in the culvert to the pool below the culvert should be avoided for all cases. Where fish passage is required and a hydraulic drop is unavoidable, it's magnitude should be evaluated for both high design flow and low design flow and shall not exceed the values shown below. If a hydraulic drop occurs at the culvert outlet, a jump pool of at least 2 feet in depth shall be provided.

Species/Life Stage	Maximum Drop (ft)
<input type="checkbox"/> Adult Anadromous Salmonids	1
<input type="checkbox"/> Adult Non-Anadromous Salmonids	1
<input type="checkbox"/> Juvenile Salmonids	0.5

FISH PASSAGE: HYDRAULIC ROCK WEIR DESIGN OPTION**FORM 6E**☐ Native Non-Salmonids☐ Non-Native Species

Where fish passage is required for native non-salmonids no hydraulic drop shall be allowed at the culvert outlet unless data is presented which will establish the leaping ability and leaping behavior of the target species of fish.

Maximum Allowable Inlet Water Surface Elevation**Culvert** ☐

A culvert is required to pass the 10-year peak discharge without causing pressure flow in the culvert,

Allowable WSEL:

ft

And shall not be greater than 50% of the culvert height or diameter above the top of the culvert inlet for the 100-Year peak flood.

Allowable WSEL:

ft

Bridge ☐

A bridge is required to pass the 50-year peak discharge with freeboard, vertical clearance between the lowest structural member and the water surface elevation,

Allowable WSEL:

ft

While passing the 100-year peak or design discharge under low chord of the bridge.

Allowable WSEL:

ft

Establish Allowable Hydraulic Impacts

Is the crossing located within a floodplain as designated by the Federal Emergency Management Agency or another responsible state or local agency?

☐ Yes ☐ No

If yes, establish allowable hydraulic impacts and hydraulic design requirements with the appropriate agency. Attach results.

Will the project result in the increase capacity of an existing crossing? ☐ Yes ☐ No

If yes, will it significantly increase downstream peak flows due to the reduced upstream attenuation? ☐ Yes ☐ No

If yes, consult District Hydraulics. Further analysis may be needed.

Will the project result in a reduction in flow area for the 100-year peak discharge? ☐ Yes ☐ No

If yes, establish the allowable increase in upstream water surface elevation and establish how far upstream the increased water surface may extend.

Develop and run Hydraulic Models to compute water surface elevations, flow depths, and channel velocities for the low fish passage design flow, the high fish passage design flow and for the 2-, 10-, 50-, and 100-year peak or design discharges reflecting existing and project conditions.

☐ Yes ☐ No

Evaluate computed water surface elevations, flow depths, and channel velocities: ☐ Yes ☐ No

Maximum average velocity in structure at high fish design flow:

ft/s

Does the velocity exceed the maximum allowable for the structure length and design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Minimum flow depth in structure at low fish design flow:

ft

Does the depth equal or not exceed the minimum allowable for the structure length and design species? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Drop between the water surface elevation in the structure and the outlet channel for:

High Fish Passage Flow:

ft

Low Fish Passage Flow:

ft

Does the drop between the water surface in the structure and the outlet channel at high or low design fish flows exceed the maximum allowable for the design species? ☐ Yes ☐ No

If yes, modify design to avoid a drop if possible. If a drop is unavoidable modify design to meet criteria and provide a jump pool at least two feet in depth. Rerun hydraulic analyses to verify.

Water Surface elevation at inlet for the 10-year peak discharge:

ft

Does the water surface elevation exceed the allowable? ☐ Yes ☐ No

If yes, modify design to comply and rerun hydraulic analyses to verify.

Maximum Structure and Channel velocities at inlet and outlet transition for the peak or design discharge:

Range of velocities for Inlet transition:

ft/s

to

ft/s

Range of velocities for structure portion:

ft/s

to

ft/s

Range of velocities for Outlet Transition:

ft/s

to

ft/s

Do the velocities exceed the permissible scour velocities? ☐ Yes ☐ No

If yes, revise design to reduce velocities and rerun hydraulic analyses to verify, or design erosion protection.

Comparison between existing and project future condition water surface elevations for the 10-Year and 100-Year peak flow:

Cross-Section	10-Yr WSEL	10-Yr WSEL	WSEL Difference	100-Year WSEL	100-Year WSEL	WSEL Difference
	Existing Conditions (ft)	Future Conditions (ft)	(ft)	Existing Conditions (ft)	Future Conditions (ft)	(ft)
1						
2						
3						
4						

If WSELs increase, does the increase exceed the maximum elevation? ☐ Yes ☐ No

Maximum elevation:

ft

If yes, revise the design and rerun hydraulic analyses to verify.

If WSELs decrease, does it appear that the attenuation of peak flow will significantly change? ☐ Yes ☐ No

FISH PASSAGE: HYDRAULIC ROCK WEIR DESIGN OPTION**FORM 6E**

If yes, evaluate to determine if downstream hydraulic impacts are significant and modify design as appropriate.

Proposed Plan and Profile Drawing Attached ☐ Yes ☐ No

Hydraulic Analysis Index Sheet Attached ☐ Yes ☐ No